Advanced Fuel Cycle Initiative

Technical Monthly - May 2003

Systems Analysis

Transmutation Studies and Integrated Fuel Cycle Modeling

[BNL, ANL] The impact of Pu+Np fuel for a Combustion Engineering (CE) System-80 assembly design is being analyzed to see if the presence of the large water holes results in any significant differences from the results obtained for a 17x17 Westinghouse assembly. The System-80 reactor was designed for full-core MOX. ANL has provided their latest results for the Westinghouse assembly to guide the initial fuel loading.

[ORNL, BNL] Specifications on MOX assembly designs to burn weapons-grade plutonium in LWRs under the Materials Disposition (MD) program were compiled by ORNL. These results will be factored into the design studies with reactor grade Pu+Np. In addition, an assembly benchmark based on the MD assembly designs will be proposed to CEA as an alternative to the CORAIL Pu+Np assembly benchmark for collaboration comparisons.

[ANL] An *"optimized" MOX assembly* using reactor grade plutonium was developed with enrichment split of 9/6/4%Pu/HM; this enrichment split minimizes the localized pin power peaking to 1.12-1.16 in the mixed lattice of MOX and UO_2. The power sharing between the MOX and UO_2 assemblies (3.85% U-235 enrichment) is relatively equal, with the MOX burnup at discharge being about 5% higher than the UO_2 (46.6 GWd/MT vs. 44.5 GWd/MT).

[ANL] The use of burnable poisons to further reduce the mixed lattice power peaking was investigated. The introduction of Gd_2O_3 in a small fraction of the UO_2 pins reduces the power peaking in the MOX assembly, but increases the relative MOX power share. Although the localized power peaking in the UO_2 is increased, the overall peaking remains the same. Burnable poisons reduce the concentration of soluble boron needed for global reactivity control.

[ANL] For *MOX fabricated with Pu+Np*, an "optimized" enrichment split of 9.5/6/4%(Pu+Np)/HM was selected; the maximum peak-to-average power in the MOX is 1.15. In this case, the UO_2 enrichment must be increased to 4.1% U-235 to compensate for the parasitic capture in the Np. Conversely, a higher loading of Pu+Np could be used in the MOX, but this would exacerbate the localized power peaking in the MOX assembly.

[BNL] Work is continuing on the Reduced Moderator Water Reactor (RMWR) that has been developed by JAERI with industrial participation for several years. An initial set of one-group cross-sections is being generated based on the pin-cell benchmark proposed by JAERI. The one-group data will be used in the evaluation of LWR Transmutation Options.

[LANL] A second exchange of output in the NFCSim/COSI benchmarking activity has been completed, possible sources of differences are being evaluated.

[LANL] Development of cost models for reprocessing and fuel fabrication has continued with a focus on the effects of:

- -additional unit operations related to enhanced separations, and
- -dose as related to solvent degradation and fuel fabrication.

[ANL] Using the site recommendation engineered barrier system model in GoldSim, the neptunium release was found to be solubility limited if the commercial spent nuclear fuel radionuclide inventory were immobilized in borosilicate glass;

whereas, the neptunium release is not solubility limited for direct disposal of the spent fuel. This behavior is attributed to changes in the in-package chemistry conditions associated with the degradation of borosilicate glass. Because the glass degradation rate is larger than that for direct disposal of spent fuel, other isotopes become more important contributors to the estimated peak dose rate. The net effect of immobilizing the spent fuel in glass is to increase the peak total dose rate.

[LANL] A literature search regarding the advantages and disadvantages of uranium recycle was conducted and findings summarized for the Separations Group Meeting.

[LANL, ANL] Phase 1 of the project to develop a safeguards approach for a pyroprocessing fuel cycle facility that integrates safeguards technology has essentially concluded. An acquisition path analysis has been conducted to assess the four safeguards options identified for the reference pyroprocessing facility. In parallel, facility impacts of the four options have been identified and assessed. The acquisition path and facility impacts analyses form the basis for the final selection of preferred safeguards options. To complete the assessment, the technologies on which the safeguards options rely need to be developed or demonstrated in the proposed Phase 2.

[ANL, LANL] The final document for Phase 1 is being assembled and will be provided to DOE and NNSA for review in June. The document summarizes the reference process and facility, the safeguards approaches, the assessment of options, and the list of technologies recommended for further development or demonstration.

[ANL] For low conversion ratio fast reactor designs, discrepancies in the sodium void reactivity between nodal transport theory and continuous energy Monte Carlo results were investigated in detail. Significant deviations in the voided configuration eigenvalue were observed. These errors result in inferior void worth predictions for the transport results, as compared to the reference solution. In contrast, the nodal transport results are quite accurate for the prediction of gas expansion module (GEM) reactivity worth; whereas, the diffusion results greatly overpredict (by a factor of two) the leakage reactivity changes.

[ANL] Analysis techniques were developed for VHTR fuel cycle analyses using the WIMS8 code. The WPROCOL module provides a detailed representation of the coated-fuel particles in a matrix material with the resulting pin-cell cross sections used in a CACTUS whole-assembly calculation. The assembly calculation is followed by a flux recovery step in which the homogenized fluxes are combined with the heterogeneous fluxes for use in the burnup module. The WIMS8 depletion results will be compared to MCNP and DRAGON results next month.

[LLNL] DOE review of the Memorandum of Agreement between AFCI and DOE-RW continues.

[LLNL] Discussions with ANL and LANL are underway to define the Repository Impacts products that will be available this year following finalization of FY-03 funding. This discussion will continue at the planned Transmutation Criteria workshop at ANL in June.

Repository Impacts

[DOE] DOE review of the Memorandum of Agreement between AFCI and DOE-RW continues.

[LLNL, ANL] Discussions with ANL and LANL are underway to define the Repository Impacts products that will be available this year following finalization of FY-03 funding. This discussion will continue at the planned Transmutation Criteria workshop at ANL in June.

[LLNL] Bill Halsey gave a LLNL-wide Energy Directorate Colloquium talk May 21 with the title "The Future of Nuclear Energy". Intended to educate LLNL staff from a wide range of programs on the

encouraging current developments toward renewal of nuclear energy, the colloquium included information regarding the AFCI program. The talk was well received and generated interest from a variety of energy, environment, basic science and national security programs.

[LLNL] Professor Sumer Sahin from Ankara Turkey visited LLNL with discussions on hybrid recycled uranium/thorium fuel cycles, molten salt reactors and material science studies.

Issues:

[LLNL] In the flurry of funding actions following passage of the FY-03 budget, small projects carried lower priority. All funding for LLNL work on AFCI got held up at DOE-Oak for an extended time, resulting in limited activity during the month. Funds finally arrived in a LLNL account on May 27.

For more information on Systems Analysis contact Ralph Bennett: (208) 526-7708

Separations

Separations Integration

[AFCI WG] A meeting of the Separations Working Group was held at ORNL on May 13-14, 2003.

Advanced Aqueous Separations

[ANL] AMUSE Code Development – AMUSE version 2.3 was released on May 30, 2003. The most visible change for the user of AMUSE 2.3 is how reports are generated. All reports are stored in one Excel file with each report stored in a separate worksheet. Also contained in the report file are raw input and result output that may be used to generate customized reports. In order to implement these changes, the report generation code was rewritten in Visual Basic. Also converted to Visual Basic for version 2.3 was "FE_Loop", the code that is used to run multiple runs without using the front end. Visual Basic provides greater programming capabilities over the Excel 4 Macro Language. Improvements made to the model in version 2.3 include the addition of HCH_3CO_2 to the available feed components, the addition of beta AHA terms to the TRUEX D value calculations for UO_2^{2+}, Np^{4+}, and Pu^{4+} and the addition of a Tc strip (Tc.Strip) as a valid section name. Some minor bug fixes were also incorporated into version 2.3. A list of all improvements were distributed in a document along with AMUSE version 2.3.

[ANL] UREX+ Laboratory-Scale Hot Demonstration Feed – One-third-scale scoping tests of the dissolution process have been completed. Sintered UO_2 pellets were completely dissolved by 5.84 M HNO_3 in 2 hours at temperatures at 175°C and above. However, corrosion of 304L stainless steel is excessive at temperatures above 150°C. Therefore, all dissolutions will be carried out at 150°C. A full-scale test (420 g UO_2) was conducted, and about 2% of the UO_2 remained undissolved after 4 hours. An 8-hour full-scale test is planned. After dissolution, the solution should contain 450 g/l of uranium and 0.8 M HNO_3.

[ANL] Design of UREX+ Flowsheet – Flowsheets were designed for both the ANL (laboratory-scale) and the INEEL (engineering-scale) UREX+ demonstrations. Design for the ANL demonstration was limited by two factors: (1) a stage efficiency of 85% for the 2-cm contactor and (2) a limited number of stages (24) in the hot cell. For the engineering demonstration, a conservative stage efficiency of 95% was used in the calculations; >99% is expected in operation; also, the number of stages could be optimized for each process. Both demonstration flowsheets were designed to recover 99.99% of all actinides. Recovery of Cs/Sr was set at 99.9%, and Tc at >99%. The CDC/PEG flowsheet for Cs/Sr recovery was designed by INEEL. A letter report will be released in mid June describing the five solvent extraction processes that will comprise the ANL UREX+ demonstration. The flowsheets for the engineering-scale demonstration were passed on to INEEL as they were completed.

[ANL] Centrifugal Contactor Design - Construction of the 24-stage 2-cm centrifugal contactor for the CMT-205 shielded-cell facility (along with four spare motor/rotor assemblies) is complete. Quality verification for key dimensions and hydraulic performance testing were performed on the contactors, and they were found to be well within design specifications.

[ANL] Facilities Readiness for UREX+ Laboratory-Scale Hot Demonstration – Preparations continue for the UREX+ demonstration. All equipment and radioisotopes for the simulant run have been procured. Solvent preparation has started: (1) TBP is being washed to remove impurities, and (2) CMPO and CYANEX 301 are being purified. Acid solutions are being prepared and plans for preparing the simulant feed are underway.

[INEEL] Engineering-Scale Demonstration Facility Feasibility Study. A 30% design review was held April 23-24 at the INEEL on the feasibility study being completed by Washington Group International (WGI). Comments have been incorporated into the design. A major effort to implement cost-cutting design modifications was conducted. A few of the cost cutting design modifications included a reduction in surge capacity in certain areas, makeup of solvents

completed outside of this project, elimination of the sample corridor and collection of samples remotely, and use of Gubka sponge in some of the solidification steps. An over-the-shoulder review meeting was held on May 21-22 in Denver with WGI. The 60% design review is scheduled in June.

[INEEL] Cs/Sr Extraction Process Development. Laboratory testing continued for development of a chlorinated cobalt dicarbollide (CDC)/polyethylene glycol (PEG) based solvent extraction process for the separation of Cs and Sr from dissolved LWR fuel. Acid dependency data were obtained for Eu and Am using a solvent composition of 0.08 M CDC, 0.6 vol% PEG in a phenyltrifluoromethyl sulfone diluent. These data, along with dispersion number testing, indicate that a scrub concentration of 4 M nitric acid or higher is desirable to effectively scrub any extracted actinides/lanthanides and obtain good phase separation in the extraction section. The effect of dissolved TBP in the UREX raffinate on the CDC process was also evaluated. A slight decrease in distribution coefficients was observed. A CDC/PEG flowsheet was provided to ANL to support flowsheet testing planned for this summer.

[ORNL] Advanced Aqueous Separations Process Development. The testing of extractants for the group separation of the actinides and lanthanides is continuing with the testing of the BTP extractant, 2,6-bis(5,6-di-ethyl-1,2,4-triazin-3-yl-pyridine. In parallel with the BTP experiments, the bis(chlorophenyl)-dithiophosphinic acid/Cyanex® 923 system, the Cyanex® 301/Cyanex® 923 system, and the di-2-ethylhexyl phosphoric acid system are being evaluated for comparison purposes with the initial dithiophosphinic acid data and the BTP extraction data.

[ANL] REX+ Process Demonstration. The milestone "Assess Feasibility of Preparing Oxide Fuel for UREX Demonstration at ANL" from the UREX+ Demonstration Support work package was completed on May 29, 2003. This was slightly ahead of the scheduled date of May 31, 2003. There are no show stoppers for preparing the oxide fuel in HFEF at ANL-West for the UREX+ demonstration.

[ANL] Voloxidation Process Development. The milestone "Develop Test Plan for Voloxidation Experiment and Feasibility Assessment" from the UREX+ Demonstration Support work package was completed on May 27, 2003. This was slightly ahead of the scheduled date of May 31, 2003. These tests can indeed be performed in HFEF, and therefore work to support them will be continued. Discussions started with ORNL personnel on the proposed test plan.

[ANL] Fuel Preparation for UREX+ Hot Engineering Scale Experiment. Engineering Task Authorizations (ETAs) were initiated to support the Aqueous Separations Engineering Scale Demonstration Facility (ASESDF) project at the INEEL. The ETAs cover pre-conceptual studies of the special equipment, facility interfaces, and regulatory documents needed to ship spent LWR fuel from Test Area North (TAN) to the HFEF, chop the fuel into special canisters in HFEF, and return the canisters to TAN for dissolution in the ASESDF. Responsible engineers have been assigned and an initial internal meeting was held to discuss the scope of the tasks and the interfaces between the tasks. A visit to TAN has been scheduled for early June to help the assigned engineers understand handling and transportation interfaces and to establish points of contact.

Pyrochemical Separations

[ANL] Anode Materials Development. Two large monolithic RuO_2-based composite anodes, including current leads, were successfully fabricated for use in the electrolytic reduction cell. Their electrochemical performance and thermochemical stability will be evaluated during the reduction of uranium dioxide.

[ANL] Advanced Electrochemical Reduction Process Development. The second in a series of high-capacity reduction experiments was success-

fully completed. The cell configuration supported high currents, which resulted in an improved reduction rate. Design of the off-gas system allowed for efficient removal of oxygen from the cell, preventing significant reaction between uranium metal and oxygen and limiting corrosion of the cell components, and provided continuous on-line monitoring of the off-gas oxygen concentration.

Engineered Product Storage

[LANL] Technetium Product Preparation for Storage/Transmutation. A project milestone was met in May to select a technetium recovery method for the UREX technetium product stream. The method chosen was borohydride reduction of pertechnetate to the metal. This method requires prior removal of the nitric acid from the UREX Tc product solution, followed by re-dissolution in water, cation exchange to remove impurities, making the solution basic, adding BH_4^-, and generating technetium metal by a slow addition of acetic acid. The product is a metal powder that stages the technetium for conversion to a solid metal form for storage or transmutation. A discussion was held with INEEL personnel concerning the technetium product that will be generated from the engineering scale UREX experiment. A number of options were considered and further details will be gathered on these options for evaluation by the INEEL flowsheet design team.

Spent Fuel Treatment Facility Design

[INEEL] Spent Fuel Treatment Facility (SFTF) Design Support. Comments from the Separations Working Group members were incorporated into the Spent Fuel Treatment Facility (SFTF) High-Level Functions and Requirements (F&R's) for the facility. A revised draft was given to the working group at the May meeting in Oak Ridge for final comments. Preconceptual design is scheduled to begin in mid-August.

[WSRC] Deployment Options. The Deployment Options Activity Team met during the 2-day Separations Working Group (SWG) meeting, updated the planning matrix, and reached agreement on strategic deployment options. A presentation was delivered to the working group that featured the latest deployment plan and schedule of activities for the remainder of FY03. Rev 2 of the SFTF Deployment Planning Matrix was issued to the team. The Deployment Options Activity Team has used this matrix as just one of several tools to ensure the approach to a deployment plan will be consistent with the vision and plans of the other SWG teams.

Advanced Process Development

[LANL] Actinide Crystallization Process. A milestone to complete fabrication of the mid-sized crystallization equipment for the ACP was accomplished. A jacketed glass vessel with associated condenser, chiller, thermocouples, pumps, traps and vacuum system will be used for crystallization runs to gather important data for the process design. Nitric acid solutions of uranium (VI) containing fission product elements will be concentrated by removing nitric acid under reduced pressure to give controlled crystallization of uranyl nitrate. Factors controlling crystal composition, size and morphology will be evaluated as well as the decontamination of the crystals with various washing approaches. This data will be crucial in the design and operation of the loop crystallizer system.

EBR-II Spent Fuel Treatment

[ANL] Blanket Element Processing. Twenty-four kilograms of heavy metal from blanket material were processed in the Mark-V electrorefiner during the month of May. Processing the blanket fuel serves to increase the plutonium content in the salt in support of transuranic (TRU) recovery tests. A total of 263 kilograms of fuel has been treated in FY03.

[ANL] Pyroprocess Modeling. In support of TRU recovery tests, the electrorefiner process modeling code is undergoing off-line testing to verify it can model liquid cadmium cathode (LCC) operations.

[ANL] TRU Recovery. Fabrication activities were

completed on the additional items of support equipment needed for liquid cadmium cathode (LCC) handling. The qualification test procedure for operation and maintenance of the LCC was revised to include comments from technical, operations, quality assurance, and safety personnel. Qualification testing of the LCC handling equipment was initiated in the Fuel Conditioning Facility (FCF) Mock-up Area. The advanced U/TRU recovery developmental system is being assembled in the mock-up glovebox for initial testing. Assembly and initial testing of the data acquisition and equipment control system is progressing.

[ANL] Electrorefining Process Development. Several developmental electrorefiner experiments were completed in the test series initiated last month to determine the effectiveness of intermittent uranium removal from the cathode, by scraping, as a function of the amount of uranium deposited and deposition conditions. Although the test matrix is not completed, intermittent scraping seems to be more effective than constant scraping at removing uranium from the cathode surface.

[ANL] PYROX Process Hot Laboratory-Scale Demonstration. The milestone "Complete Modifications to Support Laboratory-Scale PYROX Demonstration" from the Pyrochemical Oxide Treatment Process Demonstration work package was completed on May 7, 2003. This was slightly ahead of the scheduled date of May 31, 2003. The equipment in the Hot Fuel Examination Facility (HFEF) has now been modified to support a demonstration of PYROX with irradiated fuel. The equipment will first be subjected to a check-out process with non-irradiated material before hot testing in July. An engineering package has been initiated to begin development of engineering scale PYROX equipment for operation in the HFEF hot cell.

[ANL] Ceramic Waste Form Development. The milestone "Establish Source of Zeolite for Ceramic Waste Production" from the Ceramic Waste Development and Qualification work package was completed on May 19, 2003. This was slightly ahead of the scheduled date of May 31, 2003. A piece of equipment to grind zeolite to the required particle size has been identified. Procurement of this grinder will result in significant savings over having the zeolite vendor perform the size reduction. Modern Process Equipment has completed the grinding of 200 kg of zeolite 4A pellets to support ceramic waste form scale-up testing. Delivery of the material is scheduled for June. Three bids have been received from vendors regarding the procurement of the prototype pressureless consolidation furnace for ceramic waste scale-up. Bid review will be initiated in June.

Six samples of ceramic waste form that had been heated at 400 or 500°C for up to 1 year were prepared and submitted for XRD analysis to determine effect of heating on phase distributions. Additional tests will be conducted at temperatures up to 900°C to generate a time-temperature-transformation graph for qualification. Five ceramic waste form samples made with various salt/glass/zeolite ratios were submitted for XRD analysis to measure the amounts of halite. These materials will be subjected to product consistency tests (PCTs) to measure the sensitivity of the test response to waste form composition.

Characterization of samples of ceramic waste form material obtained using an experimental sampling method continued. This sampling method may be used for consistency testing from production-scale waste forms. Additional samples were prepared for and examined by scanning electron microscopy. Leachates from product consistency tests were analyzed. No significant differences were observed between bulk material and material obtained by the new sampling method. Elemental analysis of ceramic waste form material containing ^{238}Pu continued. Samples were dissolved and prepared for analysis. New methods developed recently for analysis of actinides will likely be used for this analysis. This material is being used to evaluate radiation damage effects in the ceramic waste form. Compositional data will be used to help interpret results from leach tests performed on this

material.

[ANL] Metal Waste Form Development. Results from long term leach tests of metal waste form samples were analyzed and the results added to the database. Samples of leached metal waste form were prepared for analysis of corrosion products by transmission electron microscopy. These samples were prepared by ultramicrotomy, which also demonstrates acquisition of additional sample preparation capability.

Three additional Smart 16 vacuum pumps from Vacuum Research Corp. were delivered to ANL-W for eventual use in the production metal waste furnace, cathode processor, and the casting furnace. As with the first pump received earlier, the three new pumps will be modified to improve remote handling and enable easier in-cell parts replacement.

For more information on Separations contact
Jim Laidler (630) 252-4383

Fuels

Integration

[NTD] The NTD attended the GEN-IV program planning meeting held in Washington, D.C. on May 8, 2003.

[NTD] Budget and descriptive input for the fuel development section of the program plan was developed and submitted to program integrator (SNL).

[All] Third FDWG meeting was held in Idaho Falls, on May 21-22, 2003. ANL, INEEL, LANL, ORNL and WSRC participants DOE AFCI fuel development manager attended the meeting.

Series One Fuels Design, Specifications and Analyses

[WSRC] A draft white paper "Evaluation of Initial Market for MOX from Recycled Commercial Spent Nuclear Fuel" was distributed to FDWG members. Comments are being resolved and incorporated. The white paper will be issued in early June.

[LANL] Various sections of the Series One Implementation plan are being drafted.

Series One Fuel Development & Fabrication

[LANL] The ionic conductivity and the oxygen diffusivity for intrinsic nonstoichiometric ceria were calculated in a wide range of temperatures and partial oxygen pressures. The model was validated against empirical data and the methodology will be used to model diffusion in actinide oxides with a focus on Series One fuel compositions.

[LANL] A paper on A MODEL OF DEFECT THERMOCHEMISTRY IN NON-STOICHIOMETRIC CERIA was presented at the CALPHAD XXXII International Conference on Phase Diagram Calculations and Computational Thermochemistry, May 25-30, 2003 La Malbaie, Quebec, Canada.

[LANL] In preparation for He bonding of the LWR-1 fuel pins, weld parameters were developed for Zr-4 fuel pins (~1/2 length) which achieved reproducible top and bottom plug welds free of leaks and gross defects as confirmed by visual examination, metallography and He leak testing.

[LANL] Processing parameters from the MD MOX experiment have been retrieved from archive. The oxide sintering furnace has been repaired and a blank sintering run has been performed. Oxide feedstock powders for the LWR-1 experiment have been prepared. Pellet fabrication will begin in June.

Series One ATR Irradiation Experiments

[INEEL, LANL] Work on test plan is continuing. Initial assessment indicates a Linear Heat Generation Rate (LHGR) of < 12kW/ft is desirable.

Series Two Fuel Design Specification and Analyses

[ANL] Milestones were met with the issuance of updates to three program documents: Low-fertile Transmutation Fuel Specification for Metallic Fuels, Functions and Requirements for Metallic Transmutation Fuels, and Five-Year Fuel Development Plan for Metallic Fuels.

[LANL] Nitride fuel portion of the implementation plan is being drafted.

Series Two Nitride Fuel Development

[LANL] Three of the three non-fertile and two of the three fertile nitride compositions for the AFC-1AE test were fabricated by a modified fabrication technique and inspected. The new fabrication technique appears to have improved pellet integrity.

[LANL] In order to further study the role of temperature and dose on the irradiation effects in ZrN, Xe was implanted into ZrN at liquid nitrogen temperature with fluences of 2E16, 4E16, and 6E16 ions/cm^2 were evaluated with grazing incidence XRD. A sample with a fluence of 2E16 ions per square cm was implanted at 350 degrees C as well. Results show peak broadening, which is expected, and some anomalous peak growth. Further examination of the samples is being conducted using transmission electron microscopy.

[ASU, LANL] Fracture toughness and Vickers hard-

ness tests have been carried out in ZrN samples with and without post-sinter heat treatment, and an improvement in mechanical properties has been observed with heat treatment. Preliminary results of microprobe studies of composition of samples before and after heat treatment indicates that heat treated samples are richer in N and O than untreated specimens, suggesting that stoichiometry and chemistry of the grain boundaries can be important to the mechanical properties of fuels in service.

[ANL] Two of the AFC-1A,C non-fertile nitride fuel rodlets, which had been removed from consideration for inclusion in an actual irradiation capsule due to pellet damage, were settled into the bond sodium and radiographed. This was undertaken to determine if any additional damage to the nitride pellets would result from this step in the rodlet fabrication process.

Series Two Metallic Fuel Development

[ANL] Two diffusion couples (Pu-10Np-40Zr and Pu-12Am-40Zr vs. HT-9) were prepared and annealed at 650ºC for 200 hours. They are currently being prepared for SEM examination.

[ANL] Preliminary SEM examination of two annealed diffusion couples (Pu-40Zr and Pu-10Am-10Np-40Zr vs. HT-9) were completed. No indication of liquid phase formation was noted, and no low-melting Fe containing phases were observed.

[ANL] DTA/DSC and TMA measurements up to 900°C were performed on a Pu-10Np-40Zr sample with no indication of liquid phase formation.

[ANL] A 35U-35Pu-30Zr metallic alloy sample was sectioned and is in preparation for characterization and analysis.

[ANL] Several weeks were taken to perform an extensive radiological decontamination operation of the Casting Laboratory glovebox used in the fuel fabrication process. This was necessitated to lower the doses being received by personnel involved in the AFCI fuel fabrication effort.

[ANL] Pu-Am feedstock was transferred into the Casting Laboratory glovebox in preparation for the upcoming AFC-1F fuel fabrication campaign.

Series Two Advanced Fuel Forms

[LANL] TEM foils of RuAl, "Fissium" ($Mo_{0.5}Ru_{0.2}Pd_{0.15}Rh_{0.15}$), NiAl, ZrN, FeAl, MgO, Y_2O_3- Stabilized cubic ZrO_2, and $MgAl_2O_4$ (spinel) were prepared for the insertion in the STIP IV irradiation.

Series Two ATR Irradiation

[INEEL, ANL] The procurement contract for fabrication of the AFC-1 east flux trap baskets was issued and approved. Four cadmium-containing baskets for use in the AFC-1B,D fuel experiments to be inserted in the ATR next month were fabricated by ANL-W and are scheduled to be transported to the ATR on June 3.

[INEEL] The ATR canal storage grid for the AFC-1 experiments was placed in the canal prior to 131A outage to support receipt of the test assemblies.

[INEEL] Neutronics, thermal hydraulics, and structural analyses were finalized for the AFC-1experiment irradiations. Engineering Design Files (EDF) were issued, reviewed, and approved. Theses EDFs were completed in support of the Experiment Safety Assurance Package (ESAP).

[INEEL] A sample of the Primary Coolant System (PCS) was taken in order to determine a baseline of the PCS chemistry. The reactor PCS will be sampled weekly for cadmium during AFC-1 irradiations.

[INEEL] The ESAP was revised to reflect the AFC-1B, 1D and two dummy capsules to be inserted during ATR cycle 131A. Review and comments by Nuclear Engineering and Safety and Operations Review Committee were incorporated and the document was prepared for final review and approval.

Fuels continued

[INEEL] All documentation and work orders were finalized for receipt on June 4 of the experiment assemblies AFC-1B and 1D.

[INEEL] The Draft AFC-1 A-D Test Plan was finalized. Hardcopies will be distributed by the INEEL to the Fuels Working Group members.

[ANL] The AFC-1B,D non-fertile metallic fuel experiment capsules were packaged in a 6M drum; they are scheduled to be loaded onto a truck and shipped to the ATR on June 3.

[ANL] The linear powers for AFC-1Æ and AFC-1F rodlets were calculated by INEEL's physics staff based on final enrichment level specifications. The peak linear powers in each experiment satisfied the design objective of 30 kW/m. The memorandum reporting these results is in draft and will be finalized next month.

[ANL] A revision to the PIE Plan was completed and issued which covers the upcoming AFC-1Æ,F fuel tests. The revision also incorporated the previous PIE Plan for AFC-1B and -1D so that all AFC-1 PIE information is contained in a single source document. This revision fulfilled the May deliverable to issue the Draft AFC-1Æ,F PIE Plan.
[ANL] The Fabrication Data Package for the AFC-1B,D non-fertile metallic fuel tests were completed and submitted to the INEEL for review and approval.

Series Two FUTURIX Irradiation
[ANL, LANL] Plans are being made for a delegation of CEA fabrication engineers to visit both ANL-W and LANL during the week of July 21 as part of the process to qualify both laboratories to fabricate the experimental fuels for the FUTURIX test.

Looking Ahead
A transmutation criteria meeting will be held in Chicago on June 18 and 19. Fuel development NTD will attend the meeting.

In June, the status of LWR-1 test preparations will be reviewed and a decision will be reached on the feasibility of November insertion into ATR.

For more information on Fuels contact Kemal Pasamehmetoglu: (505)667-8893

Transmutation

PHYSICS

Cross-Sections

[ANL] A first set of sensitivity coefficients produced by a simulated adjustment of cross sections was generated for the TRAPU-1 irradiation experiment.

Codes

[ANL] For the low-density-region treatment in the fuel-cycle method code-development work, the first order nodal spherical harmonics and first order nodal integral approaches were tested and shown to work properly. Both methods conserve neutrons in all applications.

A beginner's MCNPX class was conducted in Santa Fe, NM, with 23 students attending.

We modified MCNPX to calculate double differential cross sections and verified the INCL4 physics model with 1.2 GeV protons on 208-Pb. Validation of the INCL4 and ABLA model implementation in MCNPX was done in collaboration with CEA-Saclay.

MCNPX code developments this month also included WWG mesh-geometry-plotting superimposition and auxiliary input-file read and encryption capability.

MALIBU

[ORNL] We reviewed the MALIBU Program data and final ARIANE report (a previous Belgonucleaire Project on UO2 and MOX isotopic analysis) in preparation for discussions at the MALIBU Program Committee Meeting scheduled in June. ORNL experience from the ARIANE program will be used to provide a reference for review of the MALIBU program plan.

STRUCTURAL MATERIALS

Materials Testing

We hosted the Materials Lead for the VHTR reactor, providing a tour of the LANL CMR hot-cell facilities and discussing materials needs for the VHTR reactor.

LANL Hot-Cell Activities

Three-point-bend testing was completed on irradiated and unirradiated Mod 9Cr-1Mo at 250ºC and 500ºC and on SS-316L at 250ºC. These materials were irradiated at 250ºC-350ºC in the SINQ 590-MeV proton beam to a dose of 9.8 dpa.

Radiation Damage Modeling

The Fe-He potential was completed, and tests of the physical properties of the lattice computed with the potential matched well with experimental values.

The properties of Fe were computed for a few basic defect structures (vacancies as well as Fe and He interstitials). The results appear quite reasonable, although no experimental data is available for comparison.

The properties of small He clusters in Fe were computed to look at the stable size of these clusters.

Materials Handbook

The first draft of the Handbook chapter on HT-9 12%Cr steel was completed and submitted for formatting.

Reviews and revisions of the final draft of the Handbook chapter on Tantalum were completed. Agreements were reached with the original author at FZJ on several issues related to data sources.

COOLANT TECHNOLOGY

DELTA loop

The DELTA Loop was operated at >450ºC for >100 hours in May, mostly for cleaning the LBE of excess oxygen/oxides accumulated during earlier test operations. Injection of 6%H2/He as a cleaning gas for ~10 hours did not produce any oxygen reduction due to a limited flow

rate caused by formation of gas plug(s) inside the loop. Manual removal of ~6 lbs of oxides from the LBE surface inside the melt tank was performed.

An LBE leak through the flange after the main heater section developed during an overnight run. It was determined that thermal-expansion piping displacement caused the leakage. The flange was reassembled with new bolts and an increased preload.

A cleaning-gas injection line and a view-port have been designed for the melt tank. Also, oxygen getters (e.g., Mg) in the melt tank are being considered, and safety concerns are being investigated in consultation with international experts.

LBE Research

The OECD/NEA chartered LBE Expert Working Group met in Germany (at FZK) to determine the structure, writing schedule, and assignment for a joint international LBE Handbook development plan.

Progress on Work Package #3 (WP3) of DOE/CEA collaborations was summarized and oxygen-sensor exchange planned for July 2003.

Preliminary characterization of preconditioning oxide on HT-9 and SS-316 was completed and a report submitted, meeting a milestone.

Modeling of oxide formation for pure Fe was performed, predicting different stages of oxide formation and corrosion in oxygen-controlled LBE. We obtained JAERI's LBE loop (JLBL-1) configuration and test data and benchmarked the corrosion model with satisfactory success.

Following delivery of the FZK Oxygen Control System, two FZK scientists visited LANL for installation and instruction in the use of this system.

ACCELERATOR-DRIVEN SYSTEMS

MUSE

[ANL] The first analysis of the time-dependent pulsed-source measurements of the SC0 configuration (subcriticality level of -3200 pcm) of the MUSE-4 program was performed using JEF 2.2 data. The agreement between calculations and experimental results is quite satisfactory.

[ANL] At the semi-annual MUSE partners meeting held in Madrid, the MUSE technical program committee finalized the SC3 (-5000 pcm) and SC3/Pb (-3000 pcm) configurations. The MUSE program is scheduled to finish at the end of 2003.

MEGAPIE

A paper was prepared and submitted to the Sixteenth International Collaboration on Advanced Neutron Sources (ICANS-XVI), documenting the calculated gain in neutronic performance expected by replacing the current Mark 3 spallation target in the PSI SINQ facility with the MEGAPIE target. Several diverse figures of merit were used, and the calculated gain in source brightness was between 41% and 46%.

Peak damage rates in the structural materials of the MEGAPIE target were calculated and presented at the MEGAPIE Post-Irradiation Examination Workshop held at PSI in May. For the design goal of 6 A·h on target, the peak atomic displacements for the T91 proton beam window was calculated to be 14.5 dpa, and the He production was calculated to be 1560 appm.

Discussions were held regarding the proposed installation of fission chambers within the central rod of the MEGAPIE target. Calculations are underway to understand the sensitivity of these detectors for measuring the neutron flux.

Review of target drawings and documentation in advance of "Readiness For Manufacturing" continued as the major focus of activity. Due to cost increases announced by the manufacturing contractor, PSI has initiated an internal cost assessment.

Other DOE contributions to the MEGAPIE Project included: (1) a review of target drawings and documentation, and identification of open issues, (2) continued work on a reliability study, including a

preliminary "living" reliability assessment document, and (3) TRAC model cross-checks for accurate representation of the design and improvements to the valve control system.

TRADE

We participated in the May TRADE meeting held in Karlsruhe to discuss materials and TRADE target design.

[ANL] We completed the TRADE experiment planning for June. Plans include measurement of reactivity worth vs. burnup, noise characteristics of TRIGA at power due to bubbles, and investigation of a clean reference core.

[ANL] MSM (Modified Source Method) factors were generated at different locations for five different subcritical configurations of TRADE to use in planning subcritical reactivity measurements.

We performed an independent confirmation of the damage rates calculated by the Italian Research Organization (ENEA) for the proposed tungsten and tantalum targets. The higher atomic displacement rates calculated for the tantalum target were found to be due to the lower threshold displacement energy of tantalum (53 eV) as compared to tungsten (90 eV).

UNIVERSITY PROGRAMS

University of Texas at Austin

The proliferation resistance assessment methodology was used to provide data for nine case studies to the Blue Ribbon Committee on Nuclear Nonproliferation.

Visual coding using Visual Basic and the MS Visio software to create a user-friendly application for evaluating fuel cycles for proliferation resistance assessments is near completion. Documentation for usage of the code has begun.

Cross-section uncertainty-sensitivity evaluations are being documented for a full-core ADS simulation with MCNPX linked to ORIGEN and NJOY99 for cross-section processing.

University of Florida

We completed non-isothermal oxidation scans of SS-316L, and evaluation of the data has begun.

Machining and heat treatments of a large billet of HT-9 for use in irradiation studies was completed.

North Carolina State University (NCSU)

Proton and neutron fluxes and attendant radiation damage at SINQ Target 5 were evaluated based on two roughly similar incident proton beam profiles—a measured beam (Beam 1) and an analytic double-Gaussian profile (Beam 2). Beam 1 was more highly focused, yielding a 20% greater current density at beam center. The resulting center-beam displacement concentrations at the end of the irradiation cycle (STIP III at 10 Ah of exposure) were calculated for SS-316 at Rod 7 (close to the maximum point of neutron flux for both beams), with calculations indicating ~21 dpa for Beam 1 and ~19 dpa for Beam 2.

UC Berkeley

We identified an efficient approach for flattening the axial power shape in molten-salt transmuting reactors that involves increasing the graphite-to-molten-salt ratio in the upper and lower 20-cm of the core. The resulting overall power and radiation damage distributions obtained are exceptionally flat; the peak-to-average radiation damage rate is ~1.16.

The transmutation characteristics of molten salt reactors using two different salts were compared. LiF-BeF2 offers significantly higher fractional transmutation than NaF-ZrF4 salt; however, the LiF-BeF2 acceptable power density is an order of magnitude smaller for a comparable radiation damage rate to the graphite structure.

University of Michigan

The second irradiation of T-91 and HT-9 to 3, 7 and 10 dpa at 450°C was completed, with half the samples implanted with 100 appm He and half unimplanted. These samples will be used for corrosion (exposure) tests in the DELTA Loop at LANL.

Transmutation continued

A report summarizing the performance of fast reactor transmuters with low conversion ratios was submitted to ANL. Denatured thorium cycles offer a significant potential for increasing the transmutation rate of Pu-239 in LWR spent fuel.

A study cross-validating the Westinghouse Phoenix-P and CASMO-3 lattice physics code was completed.

University of Illinois

Procurement of major equipment and supplies necessary to complete the cooling and gas-handling systems for the LBE corrosion facility was completed. Assembly of the LBE experimental-corrosion facility continued.

LANL AFCI University Programs Leader

The LANL AFCI University Programs Leader extended the contract for the University of Illinois, adding Phase II (small-scale LBE corrosion loop), modified the UT-Austin contract to support a presentation on time-dependent proliferation resistance of various fuel cycles to the DOE Blue Ribbon Committee on Nuclear Nonproliferation, and initiated a new contract for UC Berkeley to support LANL systems studies in the area of repository impact assessments.

For more information on Transmutation contact:
Mike Cappiello (505) 665-6408

University of Nevada LV

UNLV Transmutation Research Program (TRP) Administration

UNLV TRP office reviewed and approved the final contractor bid for remodeling Room TBE B-129 for housing the ISTC TC-1. The project includes the fabrication of a robust test stand to secure the loop upright and the electrical work to run the loop and ancillary equipment. No schedule has yet been provided by the UNLV Construction and Planning Office.

The bids were opened on May 14 for the Transmission Electron Microscope room remodeling. It is anticipated that TEM will be available for research by the end of the summer.

Issues

Payments to the Khlopin Radium Institute (three contracts currently in place) were held up due to questions by the UNLV purchasing office regarding tax withholding issues. All involved UNLV offices met to discuss this issue and it is believed that resolution will be imminent.

UNLV TRP Student Research

The change of the average filling velocity during the solidification process in the molds for different convection heat transfer coefficients was analyzed. (Task 1)

The impact of the convection heat transfer coefficient on the melt solidification process was studied by using the different convection heat transfer coefficient values of h. (Task 1)

FIDAP was used to solve the induction heating model with six governing equations which can calculate the power deposition rate in the crucible. (Task 1)

An axi-symmetric geometry of the crucible for the induction heating model was used. A computational mesh of 9248 elements was generated. (Task 1)

The overall mass transfer coefficient of americium in the crucible was studied. (Task 1)

UNLV TRP Separations

For the development of a systems engineering model of the chemical separations process, the drag n drop mechanism was implemented only for the last section. (Task 8)

A label for each section to raise the events for mouse moments was created. User is allowed to raise events from any of the objects but in the user control all the objects raise events for taking input from the user. The section can be moved anywhere within the screen by clicking and moving the label. (Task 8)

The Graphical User Interfaces (GUI's) for the aqueous input stream and the organic input stream were developed. (Task 8)

The Active X technique from the Visual Basic program was successfully used and developed to run the instance of MATLAB and execute MATLAB function and export the result back to the main GUI. (Task 8)

The complete flow sheet for the chemical separation process within SIMULINK and MATLAB was studied. The development of connecting each model to individual appropriate function, like AMUSE code, will be accomplished by the end of summer. (Task 8)

The Nonlinear Programming Optimization method is being studied. A graduate assistant is also studying the numerical techniques for solving unconstrained and constrained optimization problem. He will also study the Discrete Optimization method which can be used to the systems engineering modeling of chemical separation process. (Task 8)

Preparations completed for graduate student Elizabeth Bakker to intern at Argonne National Laboratory for the summer. (Task 11)

Initiated research on the GUBKA process of containing radioactive waste. (Task 11)

Further research is being conducted into cesium/strontium storage forms. (Task 11)

University of Nevada LV

Experiments with sphagnum moss to study iodide binding were continued. The effect of flow rate, nitric acid fumes and inorganic buffering media on iodine sorption efficiency was examined. (Task 15)

The method for volatile organic iodide detection are being optimized. (Task 15)

A fullerene containing material from Aldrich has been obtained and preliminary experiments will commence. (Task 15)

Baseline XPS and FT-IR spectra have been analyzed for hydroxyapatite and fluorapatite. (Task 16)

SEM images of natural fluorapatite crystals have been analyzed, and the presence of natural inclusions containing transition metals (e.g., Ni) have been confirmed. (Task 16)

Issues

Task 15 is awaiting fullerene-containing carbon compounds from Khlopin Radium Institute collaborators (see 1.27.01, above, for details regarding contract delays).

UNLV TRP Transmutation Sciences

Track 5.0 (electromagnetic particle tracking program) was employed to study a more realistic sensor geometry as is available on the market. (Task 2)

LEED sensors are being evaluated for particle positioning. (Task 2)

Initial flow studies are being analyzed. (Task 2)
The Task 3 group is working on a manuscript describing the differences between 316 and 316L samples exposed to LBE in Russia. In the course of the manuscript, it was previously thought that the two samples had different carbon content, based on Russian analysis. In May, it was found that the carbon content is about the same in the two samples, and that differences should be attributed to surface preparation: cold-rolled vs. annealed.

SCC testing using self-loaded C-ring and U-bend specimens in acidic solution has been initiated in the UNLV Materials Performance Laboratory (MPL). Similar types of specimens were also sent to LANL for SCC testing in the molten LBE environment. (Task 4)

Simultaneously, SCC testing using smooth and notched tensile specimens of Alloys EP-823, HT-9 and 422 are ongoing in the MPL. (Task 4)

SCC tests under controlled cathodic potentials (with respect to the corrosion potential) are ongoing to evaluate the effect of hydrogen charging on cracking. (Task 4)

Localized corrosion (pitting and crevice) behavior of all three alloys is being evaluated by cyclic potentiodynamic polarization (CPP) method at elevated temperatures. (Task 4)

Metallographic evaluations by optical microscopy are ongoing. (Task 4)

Fractographic evaluations by scanning electron microscopy are being continued. (Task 4)

Mesh independence runs are being tested to find out the smallest possible number of nodes to be used in the CFD runs that maintain a certain accuracy level. (Task 5)

Some results are sought for refinements of 3-D simulation runs for a closed loop. These refinements are mainly in the elbow flow areas. (Task 5)

Sudden expansion 2-D runs are being performed with the need to track the behavior of concentration values for several modes close to the surface so that a time-averaged concentration value can be calculated from which a flux gradient of concentrations can be made. (Task 5)

The graphical depiction of the results of nuclear transport models for the neutron production source

volume, neutron capture efficiencies of specific elements of both the ^{3}He and ^{6}Li glass fiber detector systems were finalized. (Task 6)

^{3}He Neutron Multiplicity detector prototype (64 element) is completed and is now in transit to UNLV, scheduled to arrive at HRC in mid-to-late June. (Task 6)

The 304 Stainless Steel stand needed to support the ^{3}He detector system was completed in mid-May subsequent to technical drawings being transferred, approved at KRI and at HRC, and then fabricated in Oak Ridge, TN. (Task 6)

Nuclear Transport Code Models (MCNP 4B, MCNPX) that were needed to finalize the ^{6}Li glass fiber neutron multiplicity detector prototype design were verified at UNLV and also with independent models completed by Dr. Richard Craig (at PNNL). Lead target configuration for the ^{3}He system was computationally changed to that of a rectangular block target and additional MNCPX models were constructed for this target/detector geometry. (Task 6)

Neutron Multiplicity detector prototype (^{6}Li glass fiber detector) is ~90% complete for all hardware and electronic card production (for optoelectronic interfaces, light guides, signal train, firmware). Prompt signal circuitry needed for the detector to communicate with the cyclotron signals is ~70% completed. (Task 6)

Communication output hardware and software for the ^{6}Li glass fiber detector is about 95% completed. Timing “trigger” circuit for fiber detector design needed for communicating with the cyclotron beam timing system (Crocker Nuclear Laboratory at UCD) was finalized subsequent to completion and analysis of modeling results. Production of detector material (^{6}Li glass fiber) for the prototype sensor was begun and is nearing completion. Detector housing and light-tight enclosure in fabrication. (Task 6)

Researching the nuclear data bases for the Category 2 radionuclides has started. (Task 7)

Four dose coefficients from the Category 1 radionuclides were completed, which leaves about 6 more. (Task 7)

High-temperature tensile testing using specimen grips made of maraging steel in the presence of an inert atmosphere is in progress. Testing at 100^{o}C has been completed. Future tests will be performed at 300, 400, 500 and 600^{o}C. (Task 10)

A laser extensometer has been added to the Materials Testing System unit to measure the elongation along the gage section of the tensile specimen at elevated temperatures. (Task 10)

Heat-treatments of Alloy EP-823 were performed, followed by machining of additional tensile specimens. (Task 10)

Students have begun to write a program to convert CAD files, more specifically IGES types, into a textual input deck to run in Monte Carlo programs. (Task 12)

More Linux work stations for the Beowulf cluster are being built. Currently, there are 16 more slaves and 2 masters on order. (Task 12)

An open source CAD package has been procured that will read in the IGES file and convert to a MCNPX input deck. The students are currently working on understanding the format of the IGES file. (Task 12)

The control plan using LabView for the apparatus was revised. (Task 13)

A UNIX-based server for advanced mathematical simulation was procured. (Task 13)

The software FLUENT for simulating mixing and

fluid flow was procured. (Task 13)

The stirrer was shipped from the manufacturer site at the end of the month. (Task 13)

Residual stresses in welded specimens consisting of similar and dissimilar materials of heat-treated Alloy EP-823 and Type 304L stainless steel have been evaluated by ring-core method at the Lambda Research Laboratory (LRL). X-ray diffraction (XRD) method has also been used to measure the residual stresses in three-point-bent (TPB) specimens of Alloy EP-823 at the LRL. XRD method could not be used for Type 304L stainless steel TPB specimens due to their coarse-grained structure. (Task 14)

Residual stress measurements on the cold-worked and TPB specimens of both alloys have been performed by the positron annihilation spectroscopy (PAS) at the Idaho State University (ISU). Similar measurements are in progress on the welded specimens. (Task 14)

Data analyses are ongoing and metallographic evaluations have been initiated. (Task 14)

Contact has been made with the Atomic Energy of Canada Limited (AECL) to perform residual stress measurements in similar materials by using the neutron diffraction technique. (Task 14)

Issues

Some run errors are being resolved with STAR-CD. (Task 5)

Letters of Invitation and visa applications that were initiated in late February so that Russian colleagues can install and calibrate the ^{3}He-based Neutron Multiplicity detector system at the Harry Reid Center, UNLV in early summer 2003 are still in limbo. The U.S. State Department has denied visas for two of the three Russian scientists scheduled to install and test the ^{3}He detector system, which they designed and build. Visa denials are being appealed by KRI. Letters of support and clarification for the purposes of these visits (part of the HRC subcontract with KRI, etc.) were forwarded to the U.S. Consulate Section of the U. S. Embassy in Moscow in early May. No responses have been received from the U.S. Embassy in Moscow, U.S. Consul's Office in St. Petersburg, or the U.S. State Department in Washington, D.C. (Task 6)

For more information on Transmutation contact: Tony Hechanova at 9702) 895-1457.

University Research Alliance - Fellowship Program

University Programs

FY01 Fellows Alan Bolind (University of Illinois at Urbana Champaign), Thomas McKittrick (University of Massachusetts at Lowell) and FY02 Fellows Thomas Carter (University of Florida) and Will Wieselquist (North Carolina State), attended the ANS Annual Meeting in June in San Diego.

University Research Alliance, University of Nevada, Las Vegas, and Idaho State University coordinated a meeting related to the proposed University Consortium for Transmutation Research with university participants during the ANS Annual Meeting.

University Research Alliance has received FY02 Fellow Michael Gregson's thesis and has forwarded a copy to John Herczeg.

For more information on the University Research Alliance contact: Cathy Dixon at (806) 376-5533

Technical Integration

[SNL] Completed compilation and assessment of FY03 work packages from the NTDs. This led to creating a Financial Control table for the program, which was baselined on May 29. This Table shows the funding by WBS and by organization. Following review of the work packages, Technical Integration signed off and transmitted to DOE-HQ on May 15.

[SNL] Completed revision to program plan following the recommendations for the April NTD meeting. Inputs from the NTDs were received and edited for consistency. Sandia revised the prior version to improve content of the program vision.

[SNL] Continued to evaluate progress on the ESE design. Some lack of formality in the design review process was noted, but eventually responses to previous comments were formally addressed. Suggested that "Red Team" be formed to conduct internal assessment of design activity since this was major risk in program. Also, there was some indication of requirements and scope creep that needed formal control.

[SNL] Initiated development of decision map for program to illustrate logic and dependencies of critical program technical activities and critical decisions.

[SNL] Attended Separations Working Group meeting in Oak Ridge, TN

For more information on Technical Integration contact John Kelly: (505) 844-8993